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August 18, 2003

Dr. Harin Ullal, MS3212
National Center for Photovoltaics
National Renewable Energy Laboratory
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(5 copies)

Re: Twentieth Monthly Report #NDJ-2-30630-11

Dear Harin,

This letter comprises the monthly technical status report for ITN's subcontract # NDJ-2-30630-11, "Plasma-Assisted Coevaporation of S and Se for Wide Band Gap Chalcopyrite Photovoltaics", under the Thin Film Partnership Program. The reported work was performed during the eighth month of phase 2 for this contract (twentieth month overall), which is July 7, 2003 through August 7, 2003. This report describes activities performed by ITN, as well as those performed by lower-tier subcontractor Colorado School of Mines (CSM), under the direction of Dr. Colin Wolden.

1. Program Goals and Approach

Our primary objective under this program is to determine if the chalcogen in CIGS co-evaporation can be delivered more effectively by activation with a plasma. Possible advantages of plasma-assisted co-evaporation (PACE) are

- increased utilization of chalcogens,
- decreased deposition temperatures,
- decreased deposition times, and
- increased ability to tailor S/Se ratio.

University researchers at CSM are developing and testing the fundamental chemistry and engineering principles. Industrial researchers at ITN are adapting PACE technology to CIGSS co-evaporation and validating PACE process for fabrication of thin film PV. In_2Se_3 films, which are used as precursor layers in high-efficiency CIGS depositions, are the first test case for the examining the advantages of PACE listed above. Gradually, this examination is being extended to the complete high-efficiency three-stage co-evaporation process.

2. ICP Source Development

This month progress was made in both the integration of the PACE sources with co-evaporation, and the testing of the chalcogen source for the PACE feedstock. At CSM, a new glass to metal seal fitting was obtained for introducing selenium into the PACE ICP plasma, and a grounded Faraday cage and related shielding was fabricated, to minimize interference between the RF source and the other internal components such as the substrate heater and the QCM. At ITN, a low-current, high-pressure, Se source to provide Se vapor to the ICP device was designed, fabricated, and installed. Testing will be performed upon the arrival of new quartz reactor tubes, as the previous one was broken during handling: It is becoming apparent that extremely careful handling of the reactor tubes during system modification is necessary.

3. Team Activities

ITN and CSM participate in CIS team activities. At CSM, in conjunction with team interests in both microstructure and stability, investigations were begun using the Environmental Scanning Electron Microscope, to examine morphological or chemical changes that occur to chalcopyrite photovoltaic structures during exposure to moisture and heat. The sample can be exposed to variable pressures ranging from $0.1 < P < 20$ torr of either water vapor or inert nitrogen. A temperature-controlled stage can vary the temperature from $25 < T < 1000$ ºC. The water vapor and inert mode employ different detectors, and microscope operating conditions (voltage, spot size, working distance, etc.) need to be optimized for each mode. Work began and is underway at determining what those parameters are.

At ITN, progress was made on two follow-up items to the absorber sub-team's investigation of transport parameters. First, reconfiguration of existing equipment to measure defect properties by admittance spectroscopy (AS) was completed. Trap level and density as measured on an ITN device are shown in Figure 1. The data is similar to that reported by other groups.[1] AS will be measured on the team devices to determine whether measured defect densities and band gap profiles can be used together to predict device voltages. Second, efforts continue to assemble an outline for a possible publication describing the CIS absorber sub-team study of transport properties.

[1] T. Walter, R. Herberholz, C. Muller, H.W. Schock, "Determination of defect distributions and from admittance measurements and application to Cu(In,Ga)Se2 based heterojunctions", *Journal of Applied Physics*, **80**(08), pp. 4411-4420, (1996).

Best Wishes,

Ingrid Repins
Principal investigator
ITN Energy Systems

Cc: Ms. Carolyn Lopez; NREL contracts and business services
Dr. Colin Wolden; CSM technical lead

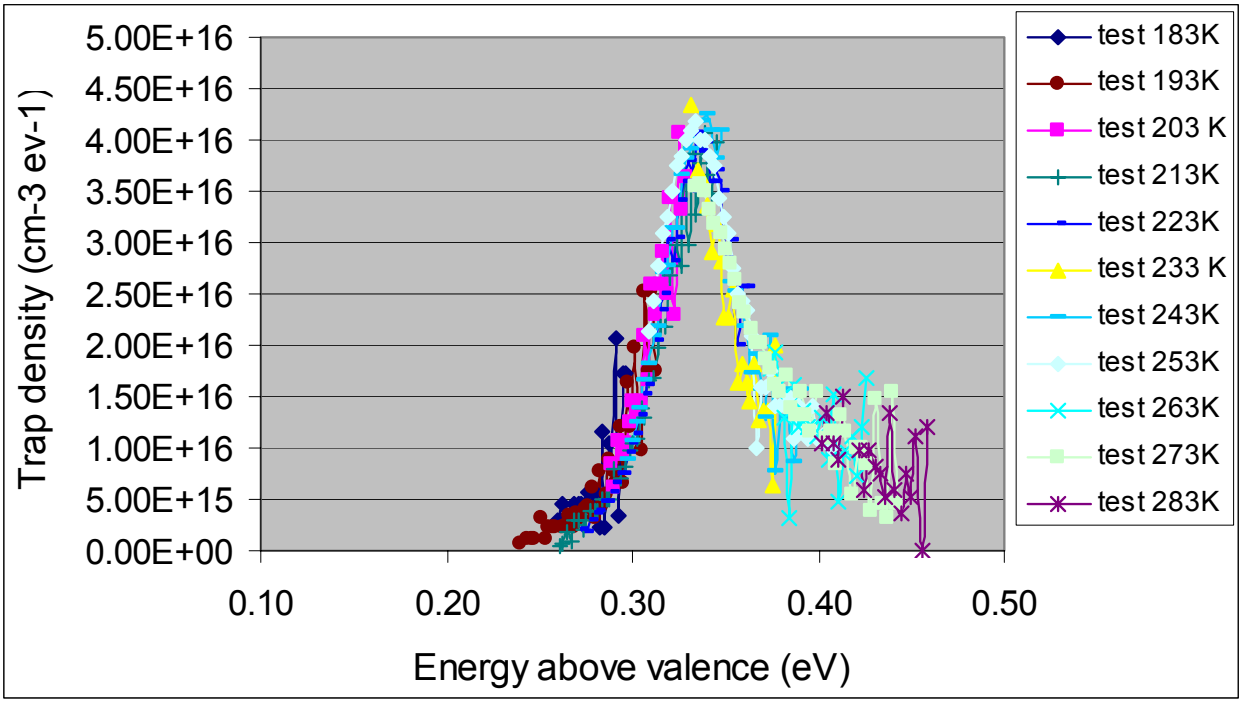

Figure 1: Trap level and density of ITN test sample.